

# LiC Toy Simulation

[www.hephy.at/project/ilc/lictoy/UserGuide\\_20.pdf](http://www.hephy.at/project/ilc/lictoy/UserGuide_20.pdf)

- Toy simulation tool based on simple detector description (vtx, its, tpc + outer si configurable)
  - Multiple scattering based on material budget of detector elements.
  - Material grouped in concentric layers
  - Layers can be active or inactive, i.e produce hits or not
  - Generates tracks and fits them based on a kalman filter implementation



# Detector Parameterization VTX

04 Vertex Detector (VTX)

05

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06 Number of layers           : 8
07 Description (optional)     : |-BeamP.-|-----Vertex detector-----|
08 Names of the layers (opt.) : XBP, XMAP1, MAP1, XMAP2, MAP2, XMAP3, MAP3, XMAPShell
09 Radii [mm]                 : 20, 26.965, 27 31.965 32, 39.965, 39, 50
10 Upper limit in z [mm]      : 1360.5, 270, 270, 270, 270, 270, 270, 300
11 Lower limit in z [mm]      : -1360.5, -270, -270, -270, -270, -270, -270, -300
12 Efficiency RPhi            : 0, 0, 1, 0, 1, 0, 1, 0
13 Efficiency 2nd coord. (eg. z) : -1, -1, 1, -1, 1, -1, 1, -1
14 Stereo angle alpha [Rad]   : pi/2
15 Thickness [rad. lengths]   : 0.00215, 0.00246, 0.00054, 0.00246, 0.00054, 0.00246, 0.00054, 0.005
16 error distribution          : 0
17 0 normal-sigma(RPhi) [1e-6m] : 4
18 sigma(z) [1e-6m]           : 4
19 1 uniform-d(RPhi) [1e-6m]   :
20 d(z) [1e-6m]               :
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# Detector Parameterization ITS

22 Silicon Inner Tracker (SIT)

23

24 Number of layers	:	9
25 Description (optional)	:	-----Inner tracker----- TPC inner wall
26 Names of the layers (opt.)	:	IT1, XIT1, IT2, XIT2, IT3, XIT3, IT4, XIT4, XTPCW
27 Radii [mm]	:	60.0, 60.257, 80, 80.257, 100, 100.257, 120, 120.257, 150
28 Upper limit in z [mm]	:	500, 500, 500, 500, 500, 500, 500, 500, 500
29 Lower limit in z [mm]	:	-500, -500, -500, -500, -500, -500, -500, -500, -500
30 Efficiency RPhi	:	1, 0, 1, 0, 1, 0, 1, 0, 0
31 Efficiency 2nd coord. (eg. z)	:	1, -1, 1, -1, 1, -1, 1, -1, -1
32 Stereo angle alpha [Rad]	:	pi/2
33 Thickness [rad. lengths]	:	0.00214, 0.01786, 0.00214, 0.01786, 0.00214, 0.01786, 0.00214, 0.01786, 0.01
34 error distribution	:	0
35 0 normal-sigma(RPhi) [1e-6m]	:	22.5
36 sigma(z) [1e-6m]	:	3500
37 1 uniform-d(RPhi) [1e-6m]	:	
38 d(z) [1e-6m]	:	



# Detector Parametrization TPC

40 Time Projection Chamber (TPC)

41  $\sigma^2 = \sigma_0^2 + \sigma_1^2 \sin(\beta)^2 + C_{diff}^2 \cdot 6\text{mm}/h \cdot \sin(\theta) \cdot L_{drift}[\text{m}]$

42 Number of layers : 60

43 Radii [mm] : 300,780

44 Upper limit in z [mm] : 800.0

45 Lower limit in z [mm] : -800.0

46 Efficiency RPhi : 1

47 Efficiency z : 1

48 Thickness [rad. lengths] :  $8.2 \cdot 10^{-5}$

49  $\sigma_0(\text{RPhi}) [10^{-6}\text{m}]$  : 120

50  $\sigma_1(\text{RPhi}) [10^{-6}\text{m}]$  : 0

51  $C_{diff}(\text{RPhi}) [10^{-6}\text{m}/\sqrt{\text{m}}]$  : 0

52  $\sigma_0(z) [10^{-6}\text{m}]$  : 120

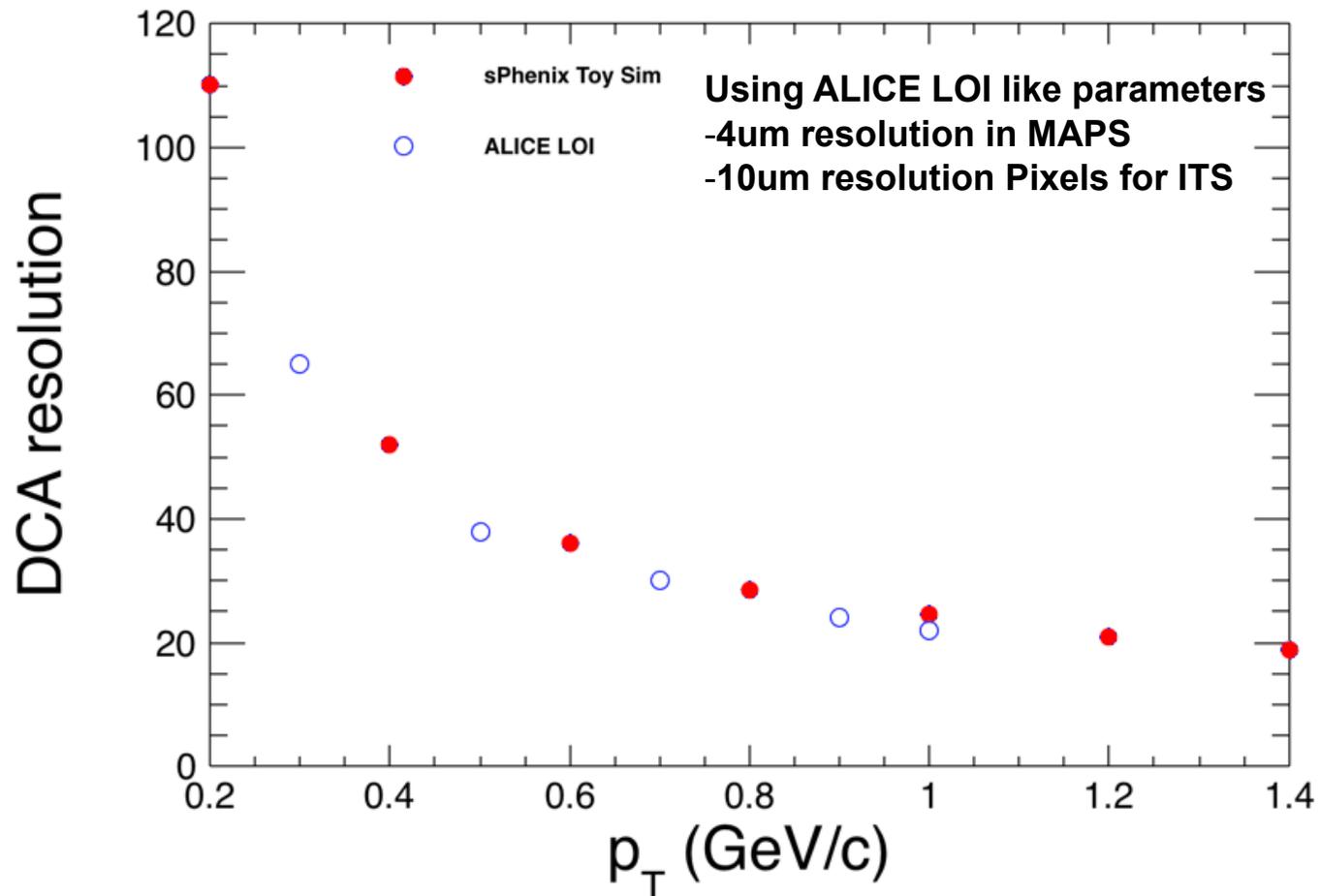
53  $\sigma_1(z) [10^{-6}\text{m}]$  : 0

54  $C_{diff}(z) [10^{-6}\text{m}/\sqrt{\text{m}}]$  : 0



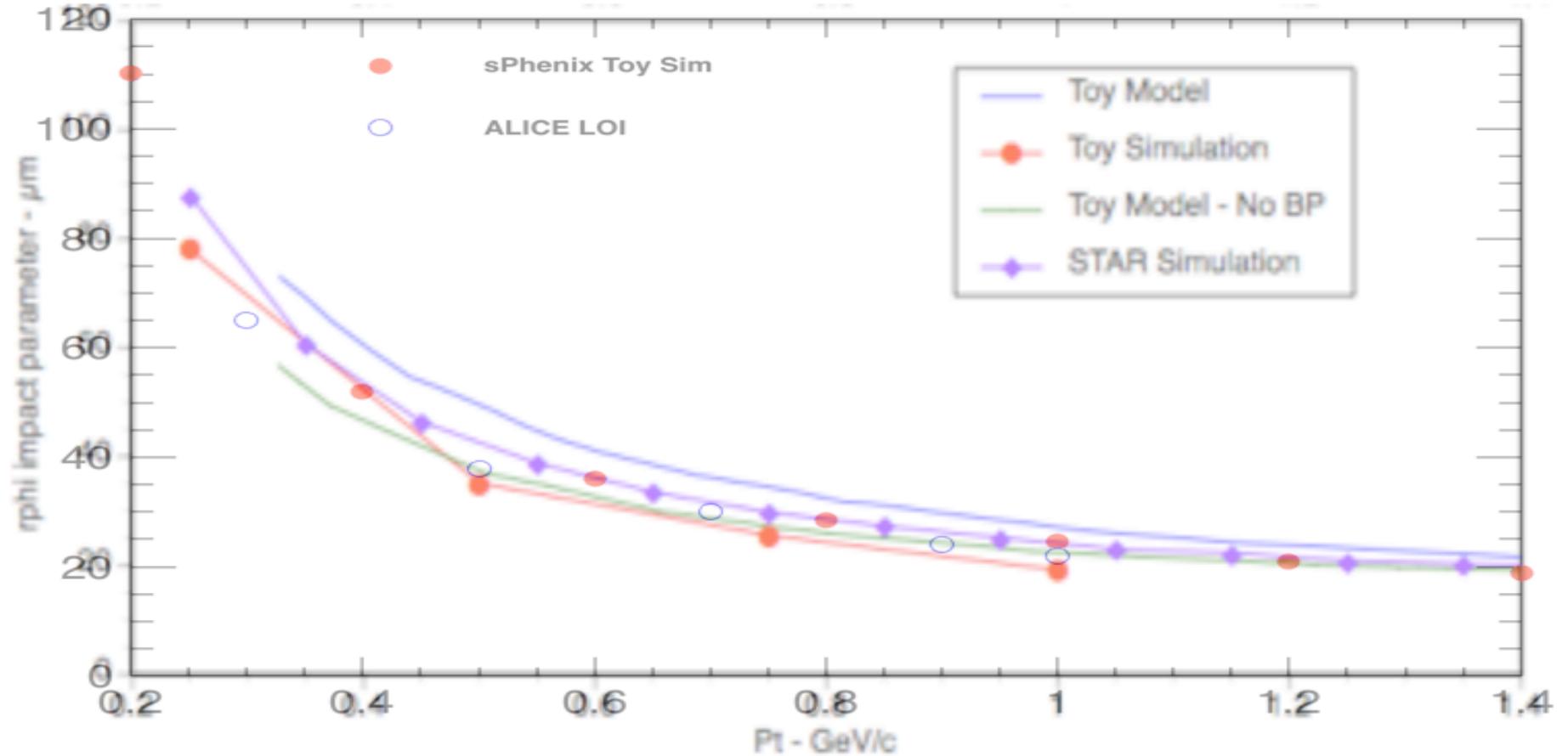
# Impact Parameter Resolution

## sPhenix LiC Toy Sim

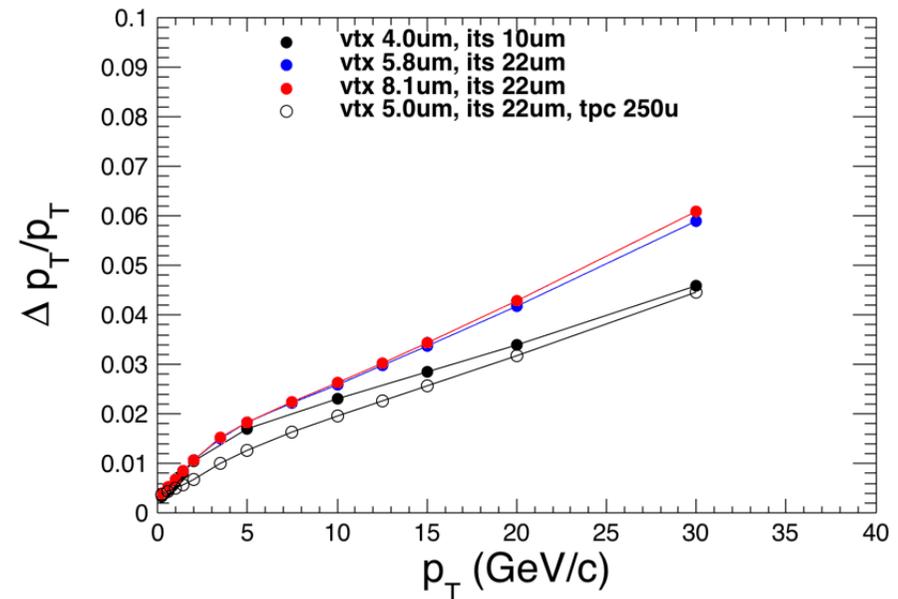
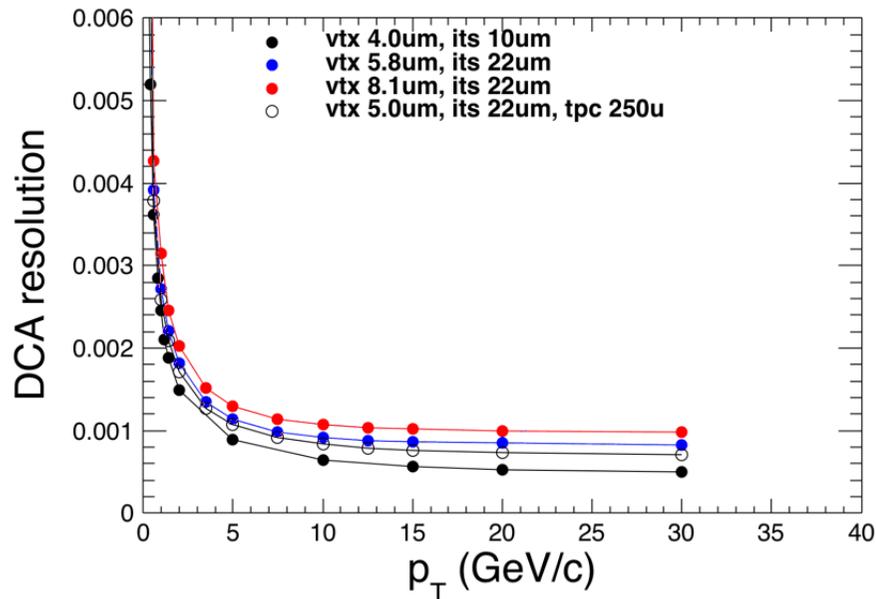


# Impact Parameter Resolution

STAR HFT, ALICE LOI, sPhenix LiC Toy Sim (ALICE like settings)



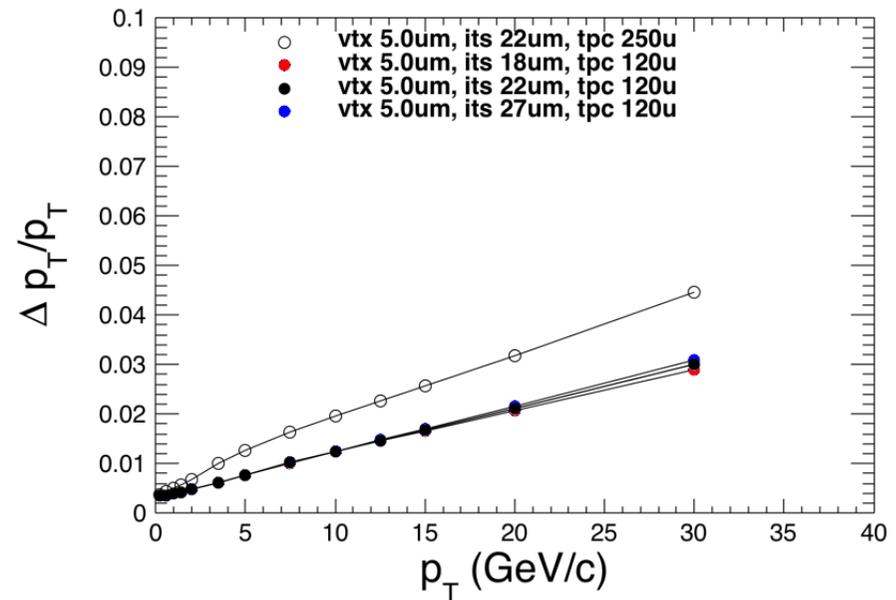
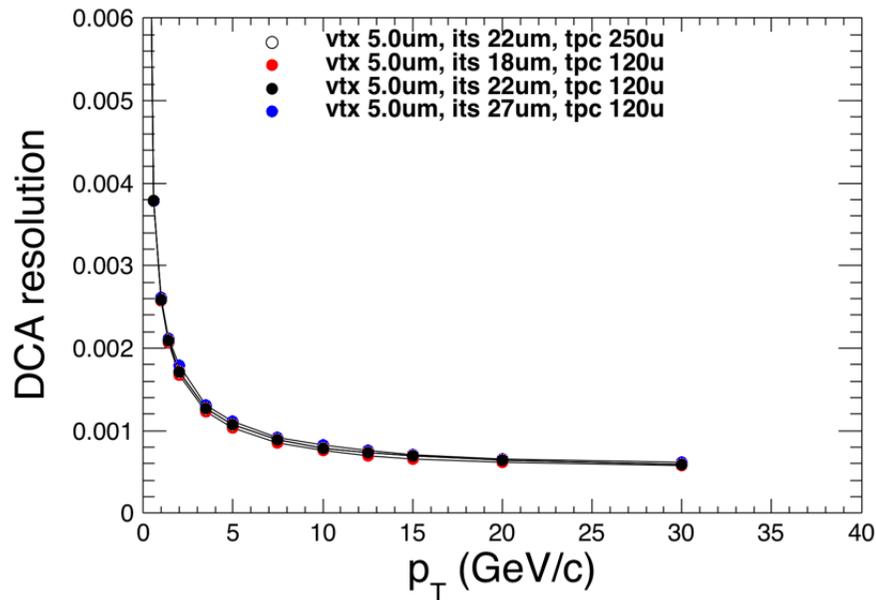
# VTX + ITS resolution study



- Check impact of changing spatial resolution for:
  - VTX:
    - 4 um (ALICE LOI default)
    - 5.8um -> 20um pixel pitch / sqrt(12)
    - 8.1um -> 28um actual pixel pitch being built for the 50um ALICE MAPs
    - Charge diffusion in the 50um sensor substrate the charge sharing between pixels should give ~5um position resolution with ~30um pixel pitch check: [https://www.dropbox.com/s/hdxbas6so9odbr9w/CMOS\\_UK\\_meeting2016.pptx?dl=0](https://www.dropbox.com/s/hdxbas6so9odbr9w/CMOS_UK_meeting2016.pptx?dl=0)
  - ITS:
    - 10um resolution pixels, i.e 2D position measurements (ALICE LOI style)
    - 22um resolution strips -> 1D measurement
  - TPC
    - 500um -> 250um



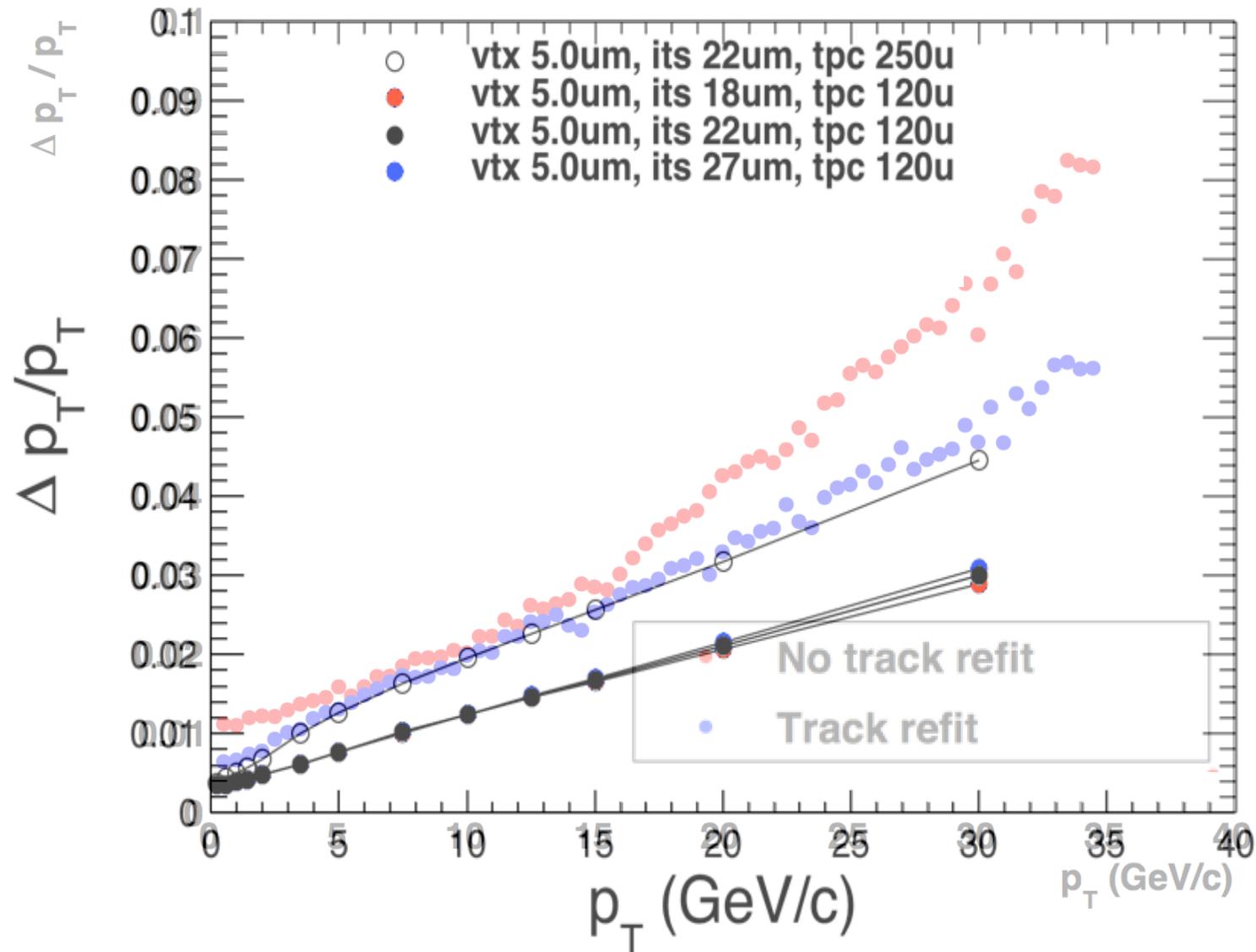
# VTX + ITS resolution study



- Using the latest numbers for the resolutions:
  - VTX 5um, ITS 22um, TPC 120um
    - Adding a variation of +/-5um resolution to the ITS to see if TPC really dominates the momentum resolution

# Momentum Resolution

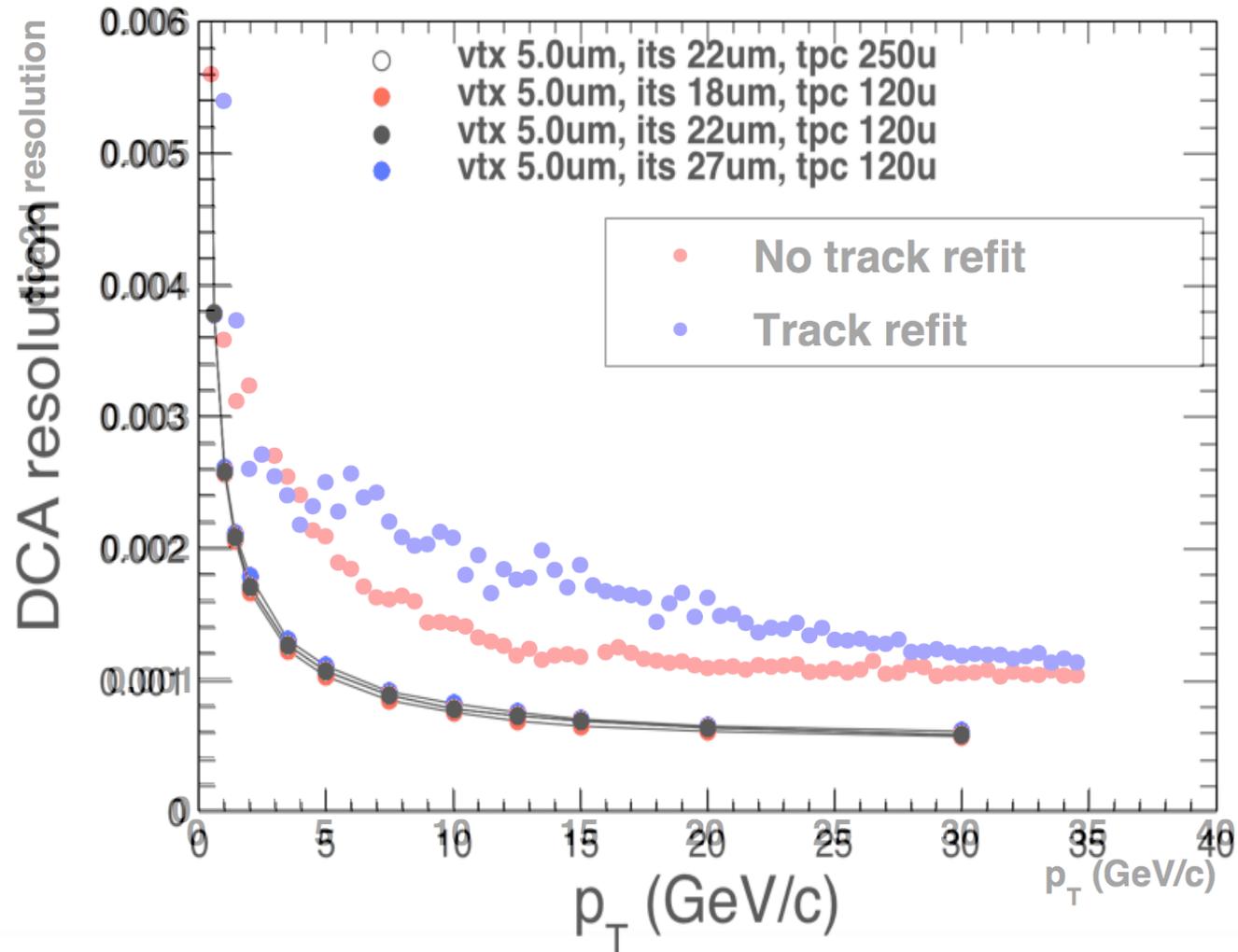
sPhenix Full Sim (Tony) vs. LiC Toy Sim



# Impact Parameter Resolution

sPhenix Full Sim vs. LiC Toy Sim

(assuming 0.5mm resolution in the TPC)



# First conclusion from toy model

- We may have some room to improve in the track parameter estimation
  - Will start investigating
- Toy model very useful for quick studies of impact of detector resolution, material budget and layer placement

# Comment on Electron reconstruction

- Limiting factor for electron momentum reconstruction is bremsstrahlung in detector material.
  - Contrary to regular multiple scattering this effect is non gaussian and has long tails-> bethe-heitler distribution
  - “kinks” in electron tracks
- LHC standard to treat electron reconstruction in silicon trackers is the “Gaussian Sum Filter” (GSF)
  - Extension to the kalman filter allowing for explicit kinks + momentum reduction in track while propagating
  - See e.g. <https://arxiv.org/abs/physics/0306087>
  - Can be complemented by reconstruction of associated ecal clusters from bremsstrahlung

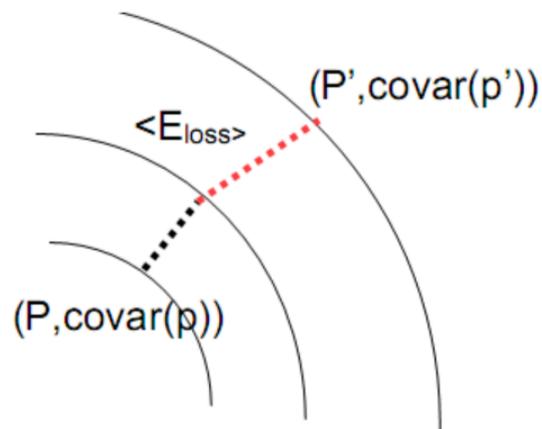


# CMS GSF electron reco

## GSF = Gaussian Sum Filter

Gaussian Sum Filter = an [extended Kalman filter tracking technique](#), which takes into account the effect of the interaction of the tracker material with a particle on its trajectory

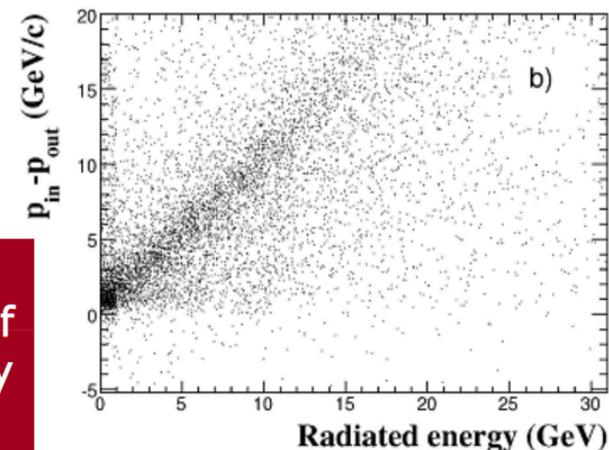
At each layer of material, re-estimate window to look for the next track hit based on Bethe-Heitler energy loss formula (approximated by a [sum of gaussians](#)). Resulting GSF fit on candidate hits has [track parameters varying vs. R](#).



January 13, 2009

unbiased  
estimator of  
total energy  
loss!

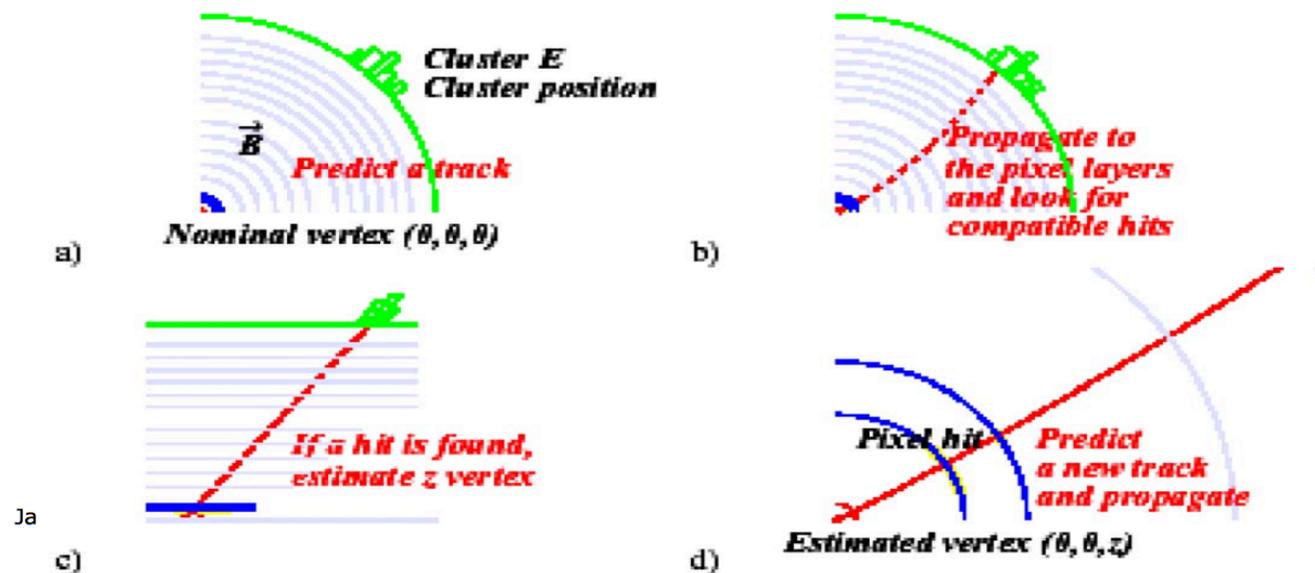
Compare  $P_{\text{in}} - P_{\text{out}}$  (tracks) with  $E_{\text{brem}}$  (ECAL)



# CMS GSF electron reco

## The CMS “GSF Electron” Reconstruction Algorithm

1. Find cluster-of-clusters = “**Superclusters**” (see A. Askew talk), use primary vertex & SC centroid to define a search road
2. **Pixel seeding**: look for 2-3 compatible hits in the road, build a candidate hit list from **inside to outside**
3. Fit trajectories using GSF algorithm with hit lists, keep the best one(s)
4. Correct electron energy for losses



# GSF for sPhenix

- Full ECAL seeded electron reconstruction including recuperation of bremsstrahlung photons works well for high  $p_T$  electrons.
  - May not be realistic for electrons from  $J/\psi$ 's
- Improving the momentum estimation using the GSF may still help reducing the impact of the material budget

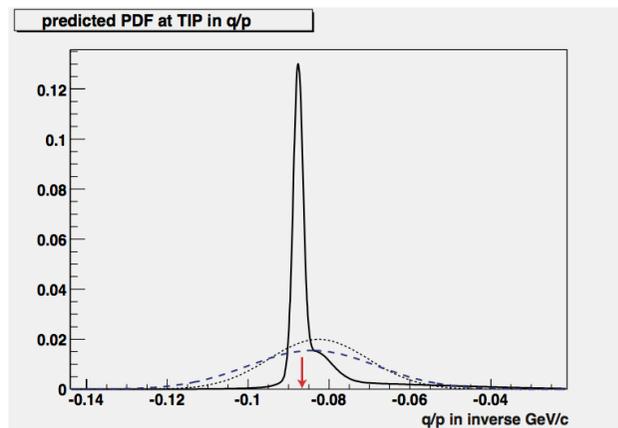


Figure 4: Estimated  $q/p$  of one single track for the GSF (solid), the KF (dashed) and the combined GSF state (dotted). The combined GSF state refers to the first and the second moments of the GSF estimate, here visualized as a single Gaussian. The arrow denotes the true value of  $q/p$ . It can be seen that the estimated PDF of the GSF is a non-Gaussian function.

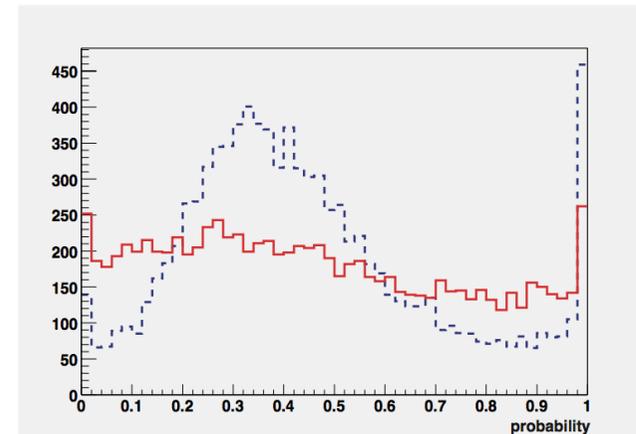
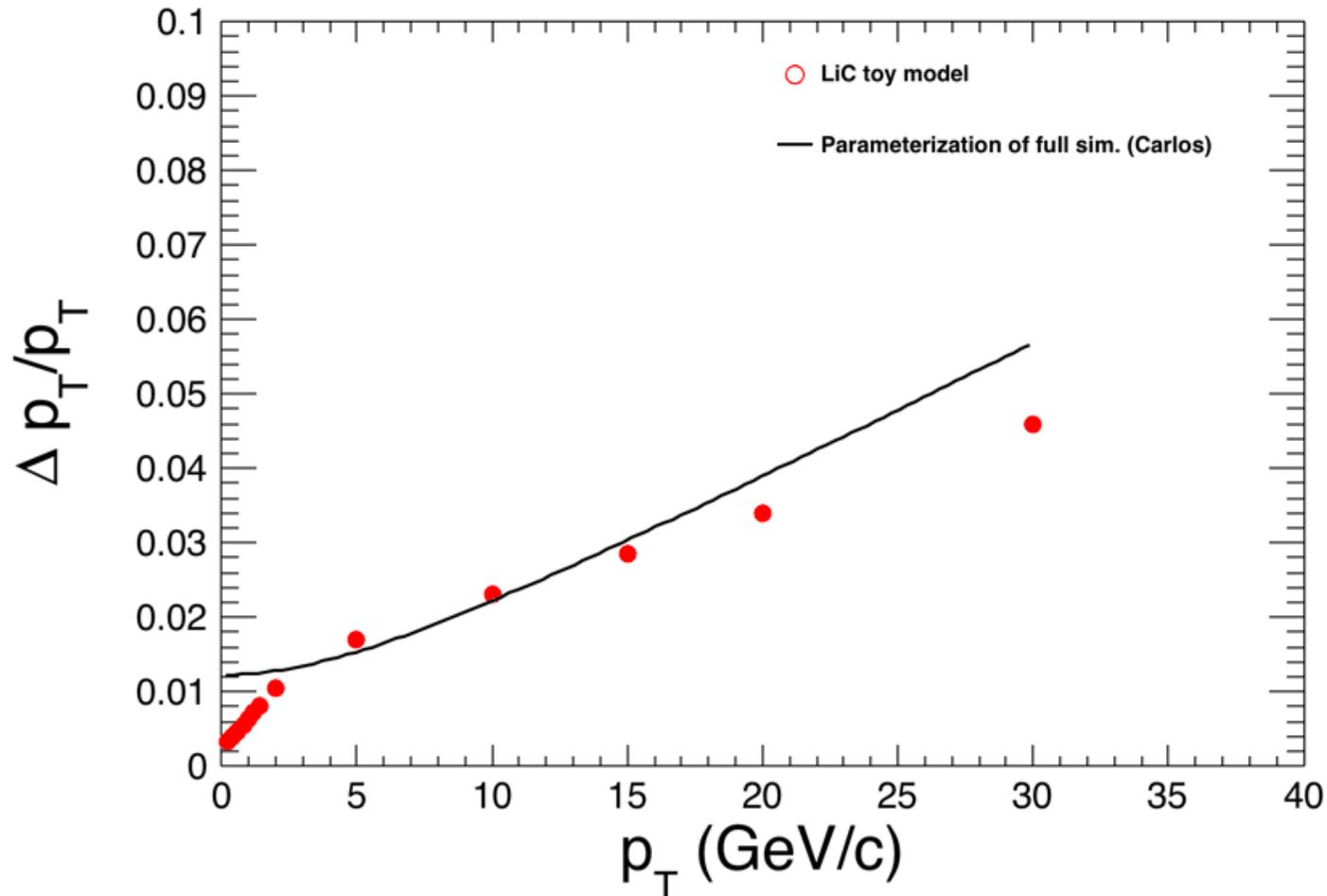


Figure 12: Probability distribution for the estimated  $q/p$  for the KF (dashed) and the GSF (solid). The specific mixture used in the GSF is a CDF-mixture with six components. A maximum number of twelve components has been kept during reconstruction. The reconstruction algorithms have been run on tracks from a full simulation.

# BACK-UP

# Momentum Resolution



- Momentum resolution very sensitive to spatial resolution parameterization of TPC hits. Currently assuming 0.5mm  $\sim$  cell size/sqrt(12)
- Low momentum part not reliable, no energy loss included in toy model

# Trying some ideas...

- Tony mentioned 4 ITS layer may be too much material for electron reco.
- 50 $\mu$ m MAPS may be difficult to procure
- Try “light” version of the inner tracker
  - 2 maps layers at 2.7 and 3.2cm radius
  - 2 ITS layers at 10 and 12cm

